

# AFRL

THE AIR FORCE RESEARCH LABORATORY  
LEAD | DISCOVER | DEVELOP | DELIVER



## ***Air Force Research Laboratory***

***8 June 2009***



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# Agenda



- **About AFRL**
- **Sample Technology Efforts**
  - Portable, renewable power generation, storage, and distribution to self-configuring grids
  - Low-cost, configurable, multi-purpose micro-satellites
  - Low-cost micro-satellite launch platforms
  - Long-life, high-density power storage and management
  - Precision location and navigation independent of GPS
- **Summary**



# AFRL Mission

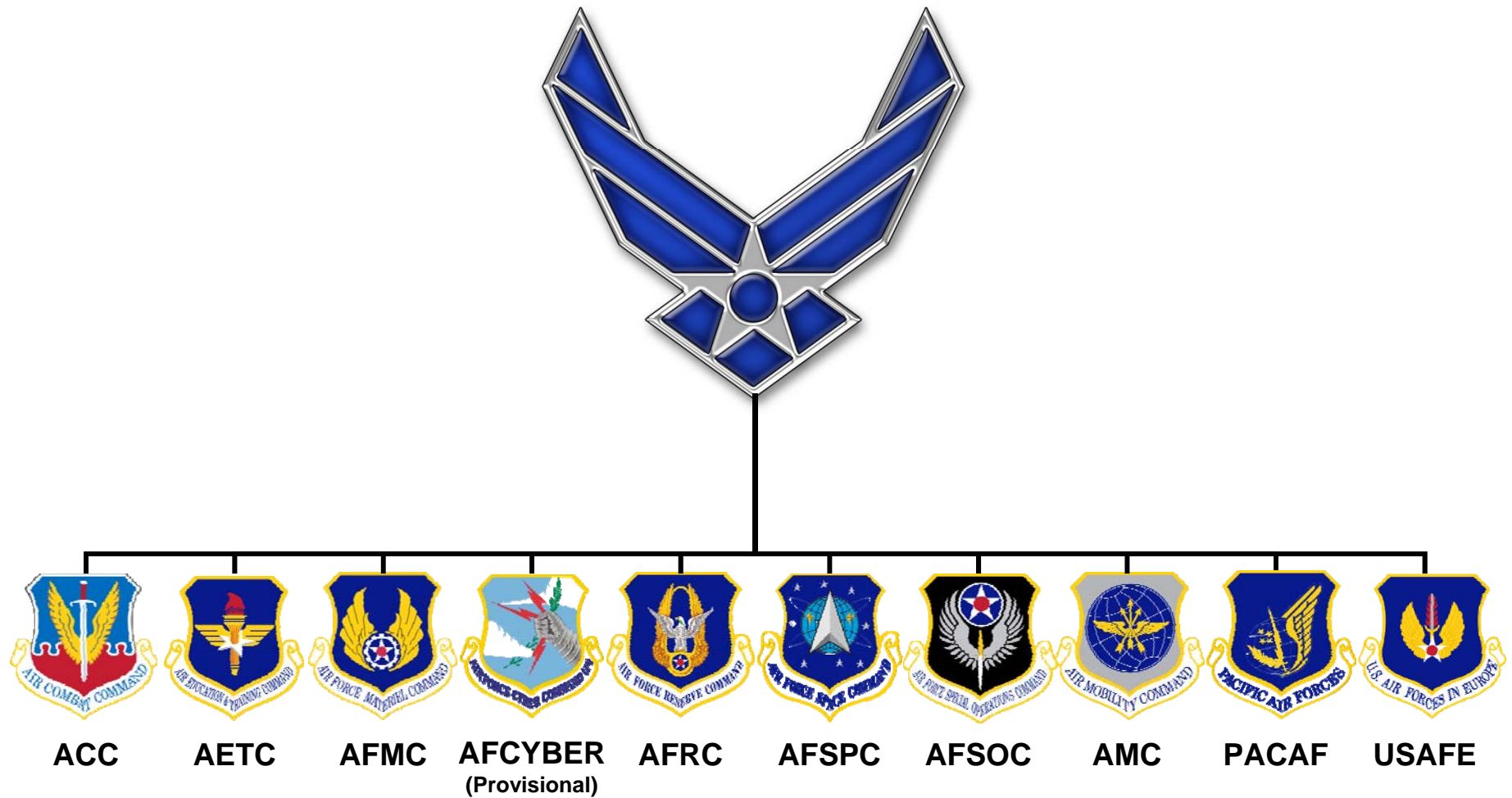


**Leading** the discovery, development, and integration of affordable warfighting technologies for our air, space and cyberspace force.

It's not just about the science...  
...it's about leadership in S&T



# USAF Major Commands





# Air Force Materiel Command



Research &  
Technology  
Development

System Development & Production

Test & Evaluation

Operation  
& Support



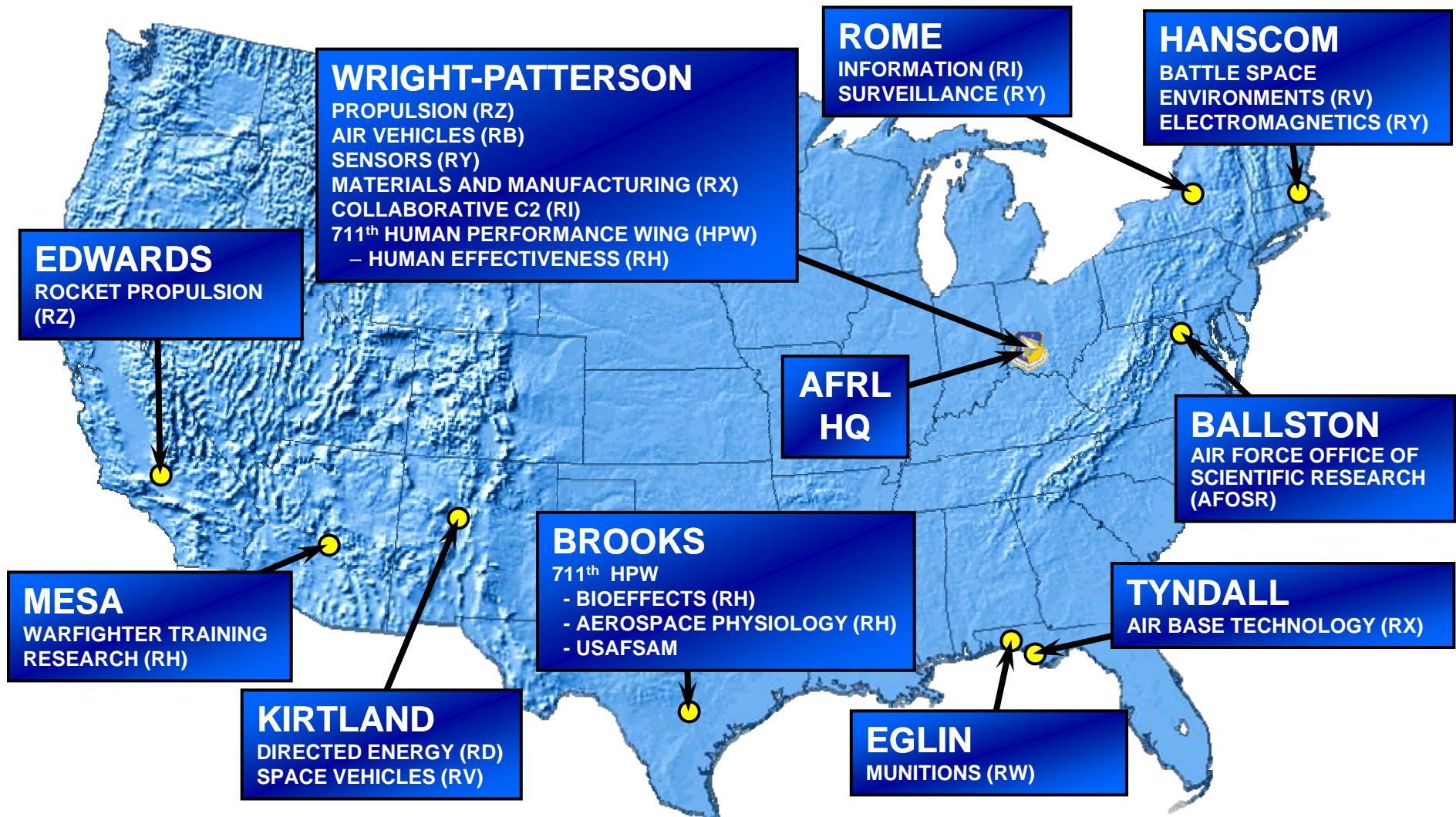


# AFRL Organization





# Major AFRL Facilities



## 40 Sites World-Wide



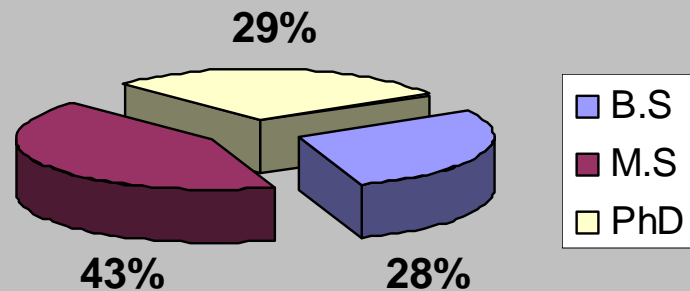


# AFRL Workforce

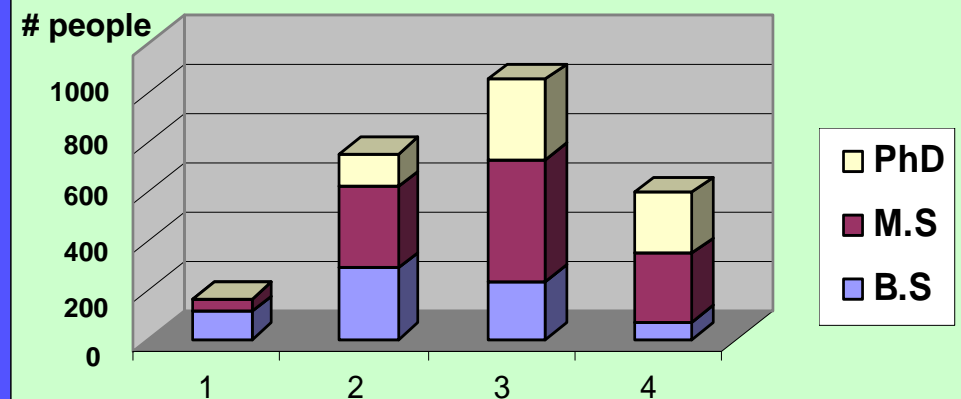


	Employees	Civilian	Military	Contractor
Total	~10800	~4750	~1450	~4600
S&Es	~ 6750	~2800	~ 850	~3100

**Civilian S&E Education**



**Education Level by Grade**

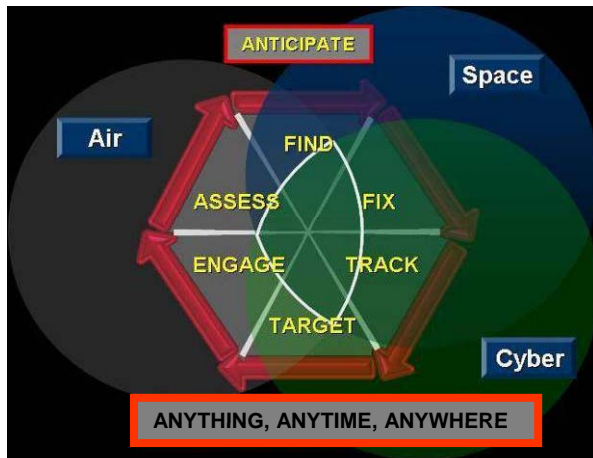




# AFRL's Core Processes Aligned to Customer Needs



## Core Process 1



### Achieve AF S&T Vision

Long-Term Focus

Lead / Discover

## Core Process 2

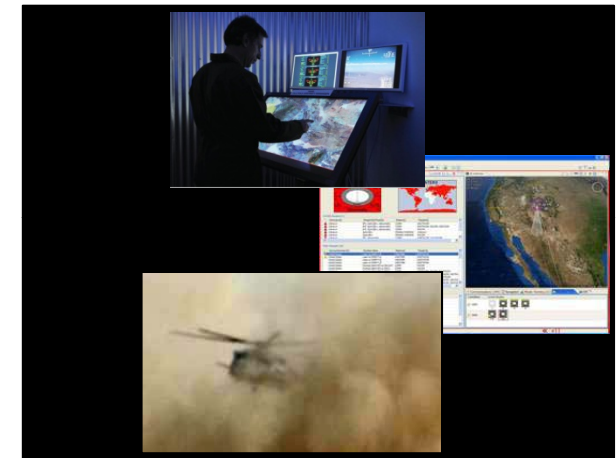


### Deliver Needed Technology Options

Mid-Term Focus

Develop / Deliver

## Core Process 3



### Deliver Rapid Response and Tech Support

Near-Term Focus

Solve / Deliver



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  - **Portable, renewable power generation, storage, and distribution to self-configuring grids**
  - **Low-cost, configurable, multi-purpose micro-satellites**
  - **Low-cost micro-satellite launch platforms**
  - **Long-life, high-density power storage and management**
  - **Precision location and navigation independent of GPS**
- **Summary**



# Portable, Renewable Power Generation, Storage, and Distribution to Self-Configuring Grids



## Flexible Solar Power System



### Concept:

Develop lightweight and thin film solar cells for integration into deployable military shelters. Skins are intended to be capable of generating efficient and reliable mobile electric power for warfighter use



### Benefits to Warfighter

- New power system will result in reduction of 60% in size and weight from current systems
- Decreasing the entire airlift requirement by 15%
- Ability to generate power on site without need for fossil fuels
- Cutting maintenance cost by 50%
- Eliminate requirements for fuel truck convoys at deployment
- Reliable, and cost effective electric power generation system with small footprint

### Problem

Current power generation systems are logistic burdens

- Constant refueling requirements
- Heavy, Bulky, and noisy
- Requires large number of airlifts
- Maintenance intensive
- Exposure of troops to hazardous environment due to fuel truck convoys at deployment location

### Programmatics

- Status
  - POC: Reza Salavani, AFRL/RXQD, DSN 523-3715
  - Current Technology Readiness Level: TRL 4
- Next Steps
  - FY09-11 TRL 6: Complete System Integration and Demonstration
  - Provide a Software analysis tool to help decision makers in applying and integrating solar power technology into airbase infrastructures
  - Lightweight flexible photovoltaic panels for integration into tent shelters at deployed locations

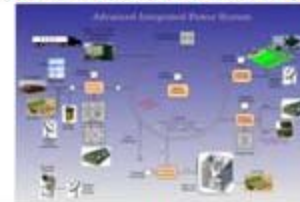


## Advanced Integrated Power System



### Concept:

Develop an advanced power grid system capable of supporting electrical power and power management requirements from renewable sources for warfighter use



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- New power grid system will result in reduction of 60% in size and weight from current systems
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- Ability to generate and distribute power on site with reduced dependence on fossil fuels
- Cutting maintenance cost by 50%
- Eliminate requirements for dependence on commercial power grid system for operation
- Reliable, and cost effective electric power grid system with small footprint

### Problem

Current power grid systems depend on commercial grid and needs too much logistic trails

- Vulnerable to power disruption due to natural disasters or enemy attacks
- Heavy, Bulky, and noisy system
- Requires large numbers of airlift for transportation
- Need for intensive Maintenance
- Possible power outage for long period of time to Mission critical C4I Equipment

### Programmatics

- Status
  - POC: Reza Salavani, AFRL/RXQD, DSN 523-3715
  - Current Technology Readiness Level: TRL 5
- Next Steps
  - FY09-12 TRL 6: Complete System Integration and Demonstration
  - Provide a Software analysis tool to help decision makers in applying and integrating various power generation technology into airbase infrastructures
  - Ability to integrate various renewable power generation technologies into the airbase power grid system for use at deployed locations

### What Is It?

- Lightweight / Thin Film Solar Cells Skins

### Warfighter Benefit:

- Reduced airlift requirements, portable power generation, lower maintenance costs

### Key Date(s):

- Complete system integration and demonstration at TRL6 projected for FY09-11

### What Is It?

- Power Grid System – Supports renewable power sources

### Warfighter Benefit:

- Reduced airlift requirements, portable power generation, lower maintenance costs, small footprint

### Key Date(s):

- Complete system integration and demonstration at TRL6 projected for FY09-12



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# Low-Cost, Configurable, Multi-Purpose Micro-Satellites

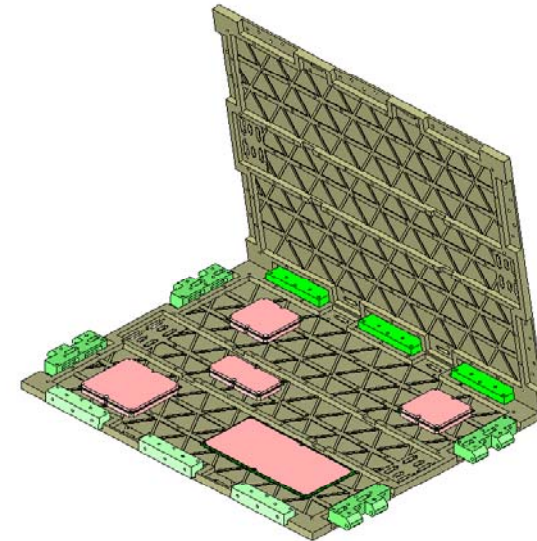




## Plug-and-Play Satellite (PnPSat)



<ul style="list-style-type: none"><li>• <b>Concept:</b></li></ul>  <p>Plug-and-play approach (similar to desktop USB) with automated mission and spacecraft design</p>	<ul style="list-style-type: none"><li>• <b>Benefits to Warfighter:</b></li><li>– Field capability on orbit within weeks or months</li><li>– Tailorable to broad range of mission needs</li><li>– Significantly reduced spacecraft development costs</li></ul>
<ul style="list-style-type: none"><li>• <b>Problem:</b></li><li>– Spacecraft development generally takes 2-10+ years<ul style="list-style-type: none"><li>• Unable to respond to urgent needs in space</li><li>• Technology often dated by launch &amp; new capability takes years to deploy</li><li>• Costs are high to maintain an engineering team for multiple years to custom design spacecraft</li></ul></li></ul>	<ul style="list-style-type: none"><li>• <b>Programmatics:</b></li><li>– POC: AFRL/RV, Maurice Martin, 505-853-4118</li><li>– PnPSat-1 completed environmental tests in Mar 09 as proof of concept</li><li>– PnPSat-2 operational pnp hardware and software will be at CDR in Sept 09</li><li>– A commercial version of pnp avionics is being implemented by Sierra Nevada Corp on ORBCOMM-2 to fly in FY10</li><li>– TRL: 5</li></ul>



## What Is It?

- Concept for building up a Satellite with Plug-and-Play Technology

## Warfighter Benefit:

- Quick reaction satellite production and deployment, reduced development costs

## Key Date(s):

- PnP Sat-1 (Proof of Concept) completed environmental tests in Mar09



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# Low-Cost Micro-Satellite Launch Platforms



Solid Propulsion Technologies for Launch	
<p><b>Concept:</b></p>  <p>Advanced solid propulsion technologies supporting lower cost, smaller vehicles/increased payload</p>	<p><b>Benefits to Warfighter:</b></p> <ul style="list-style-type: none"><li>– Rapid launch of space assets</li><li>– Augmentation of existing capabilities</li><li>– Increased payload capability, reduced cost</li></ul>
<p><b>Problem:</b></p> <ul style="list-style-type: none"><li>– Space Access is expensive and not responsive to warfighter timelines</li><li>– Warfighter needs augmentation of existing capabilities with “little” notice</li></ul>	<p><b>Programmatics:</b></p> <ul style="list-style-type: none"><li>– POC: AFRL/RZ, John Remen, DSN 525-6428</li><li>– TSSS Phase I Demos completed 2QFY09 (TRL 5)</li><li>– PAP A2S &amp; A3S to demo above technologies to TRL 6</li><li>– Family of Motors (1<sup>st</sup> stage) demo complete in FY10</li><li>– Integral part of CSM/PGS, ICBM, ORS activities</li></ul>

## What Is It?

- Solid Propulsion Technologies

## Warfighter Benefit:

- Rapid launch, increased payload capability, reduced cost

## Key Date(s):

- Multiple demos taking place in FY10



# Agenda



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# Long-Life, High-Density Power Storage and Management



## Energy Harvesting Materials and Devices

Closely Coordinated with "Electrochemical Energy Storage Materials Program"



### Concept:

### Benefits to Warfighter

- Lightweight, flexible solar harvesting devices
- Enables portable autonomous power for remote operations
- Technology could transition to the warfighter in micro UAV structures, shelters and special operations applications

### Problem

- Develop/demonstrate lightweight, flexible solar harvesting devices with significantly improved efficiency (>10%), device configuration, cost and lifetime
- Develop improved active layers for enhanced spectral response
- Design and fabricate nanostructured electrodes for increased charge transport
- Concurrently develop material and solar device processing and manufacturing science

### Programmatics

POC: Lisa Denny, AFRL/RX, DSN 785-5151  
Milestones:  
• Q3/FY08 - Reliance Power and Energy Workshop  
• Q3/FY08 - AFOSR/ Navy Joint Program Review  
• Q4/FY08 - Annual review - flexible solar devices (Phase II)  
• Q4/FY08 - Downselect materials approach  
• Q2/FY10 - Prototype Solar H2 Generator delivery/demo  
• Q4/FY10 - Flexible solar panel delivery RXB/RXQ and Demo



## Electrochemical Energy Storage Materials Program



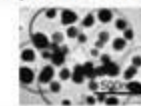
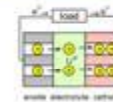
### Concept:



Vertically aligned carbon nanotube



Carbon spheres w/ encapsulated nano-catalyst



### Benefits to Warfighter

- High energy & power density rechargeable batteries for small and micro UAS
- Improved life portable fuel cell systems for in field recharge of UAS batteries and deployed comm/ comp systems

### Problem

Expand performance envelope for electrochemical energy storage devices with nanostructured materials

- Develop Nanostructured Electrode Materials
- Develop Tailored Electrolyte Materials
- Investigate New/Alternate Approaches
- Integrate & Demonstrate Prototype Cells

### Programmatics

POC: Patrick Carlin, AFRL/RX, DSN 785-5162

Milestones:  
• 1Q/FY10 - UCo D. Solid State LiD-Cell  
• 2Q/FY10 - CMU D. graphene based electrodes  
• 4Q/FY10 - EIC D. Carbon Sphere LI Battery (>600 Wh/Kg)  
• 2Q/FY11 - A123 D. 1Ah & >300 Wh/kg at 2C Cells Ultracell D. 50 XX55 Fuel Cells  
• 4Q/FY11 - UCo D. Solid State LI BA2590 (>500 Wh/Kg)

\* D. = Deliver

### What Is It?

- Lightweight /Flexible Solar Harvesting Devices

### Warfighter Benefit:

- Reduced weight, portable power generation for micro UAVs, shelters, or special ops applications

### Key Date(s):

- Flexible solar panel being delivered internal to AFRL in FY10

### What Is It?

- Materials research supporting energy storage

### Warfighter Benefit:

- Reduced weight, high energy & power density rechargeable batteries for small and micro UAVs

### Key Date(s):

- Multiple incremental technology deliveries





# Long-Life, High-Density Power Storage and Management (cont.)



 <b>Battlefield Renewable Integrated Tactical Energy System (BRITES)</b> 	
<b>Concept:</b>  Development of flexible soldier portable rechargeable battery for high power draw devices	<b>Benefits to Warfighter:</b> <ul style="list-style-type: none"><li>— Rechargeable battery capable of relatively high rate discharge</li><li>— Significantly reduced weight over legacy primary/secondary batteries</li><li>— Improved safety over currently fielded lithium ion batteries</li><li>— Enables continuous power when hybridized with energy dense source</li></ul>
<b>Problem:</b> <ul style="list-style-type: none"><li>— High power devices suffer from low energy densities and vice versa</li><li>— High rate primary batteries are discarded after partial use</li><li>— High cost associated with primary battery use</li></ul>	<b>Programmatics:</b> <ul style="list-style-type: none"><li>— POC: AFRL/RZ, Lt Mark Roosz, D SN 785-0654</li><li>— TRL: 7</li><li>— Spiral I and Spiral II transitioned and currently deployed</li><li>— Spiral III procured and in Developmental and Operational Testing</li><li>— Addresses primary need for field rechargeable Li-Ion batteries from AF SOC</li></ul>

## What Is It?

- Soldier Portable Rechargeable Battery

## Warfighter Benefit:

- Reduced weight for soldier, improved safety, improved performance

## Key Date(s):

- Spiral I & II deployed, Spiral III in developmental & operational testing



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# Precision Location and Navigation Independent of GPS



## LADAR/EO GPS Atomic Clock Nav Demo (LEGAND)

**Concept:**

**Benefits to Warfighter:**

- Precision navigation through GPS outages in military environments where GPS is likely unavailable
  - Urban canyon, indoor, jamming
  - Featureless scenes unsuitable, e.g. over ocean
- Image database/route preplanning not required
- Low cost size, weight, power applications, e.g. small UAV

**Problem:**

- GPS may be denied due to jamming or signal obscuration e.g. in urban canyon or indoors
- Inertial navigation systems drift with time and require external updates to maintain precision
- Tightly-coupling on-board "imaging" sensor(s) with low cost inertial to constrain drift of nav solution
  - No prior database of reference imagery
- Incorporation of benefit from fewer than 4 GPS satellite measurements, when available
- Atomic clock aiding for rapid GPS reacquisition

**Programmatics:**

- POC: Don Venable, AFRL/RYN, DSN 785-6127
- TRL 5 in FY 10
- Next steps
  - FY 10 real time demo of single ship LADAR and EO integrations
  - Multi-vehicle collaborative navigation study: FY 11+
  - Collaborative Robust Integrated Sensor Positioning (CRISP)

## Optical Flow Enhanced Navigation & Seeker Exploitation (OFFENSE)

**Concept:**

Vision based navigation and position updating technologies to augment GPS/INS enabled munitions and UAVs for robust precision target engagement

**Benefits to Warfighter:**

- Robust navigation for munitions and UAVs in degraded or denied GPS environments
- Enhanced capability to employ munitions and small autonomous vehicles in urban terrains
- Reduced TLE for targeting

**Problem:**

- GPS is susceptible to jamming and denial (day w/out satellites)
- Robust ego-state estimation and IMU fusion techniques are required to enable precision navigation and targeting:
  - Multi-aperture wide field of regard sensors
  - Robust ego-motion estimation
  - Robust global localization
- All source data fusion engine will allow precision navigation in the absence of GPS

**Programmatics:**

- POC: Dr. Timothy J. Klausutis, AFRL/RW, 850-883-0887
- Current TRL: 3-4
- Algorithm/Software test-bed established, performance evaluation study underway
- Milestones:
  - FY08: Ground mobile data collection
  - FY10: Captive flight test data collection
  - FY10: Performance analysis against varied environments and maneuvers
  - FY11: Real-time implementation study

## Airborne Image Gyro (ABiG)

**Concept:**

Develop a low-cost vision based navigation technology to enable precision navigation of unmanned air vehicles (UAVs) and missiles in degraded or denied GPS environments

**Benefits to Warfighter:**

- Affordable navigation sensing and processing for missiles and UAVs
- Provides low cost alternative to GPS, which is vulnerable to jamming
- Augment existing GPS navigation systems enabling precision navigation in degraded GPS environments

**Problem:**

- GPS is susceptible to jamming and denial (day w/out satellites)
- Robust ego-state estimation and IMU fusion techniques are required to enable precision navigation and targeting:
  - Robust ego-motion estimation (translation and rotation rate estimates)
- Image matching to pre-captured imagery providing precision geo-registration (position estimation)
- Multi-aperture vision and sensor fusion
- Day and night-time capable sensing

**Programmatics:**

- POC: Dr. Timothy J. Klausutis, AFRL/RW, 850-883-0887
- Current TRL: 3; Final TRL: 6/8
- Program set to start FY08-FY10 (awaiting finalization of MOU)
- International Cooperative Research & Development with Japan TRDI and U.S. ARMY (AMRDEC)
  - FY08-FY10: Startup and system definition
  - FY10-11: Preliminary processing algorithms
  - FY10-11: Hardware implementation and real-time implementation
  - FY12-13: Performance Evaluation

## What are these?

- Vision/Image based navigation and positioning technologies

## Warfighter Benefit:

- Ability to operate at high precision through GPS outages due to jamming and/or signal obscuration

## Key Date(s):

- Various key dates for each program





# Precision Location and Navigation Independent of GPS (cont.)





## Cold Atom Inertial Navigation Systems (INS)



**Concept:**

- Cold atoms: a gas of atoms slowed by lasers
- Cold atoms are incredibly sensitive to inertial forces
- Cold atom sensors enable ultra-accurate navigation w/o external reference (e.g., GPS-denied environments, space)
- Adaptable to multiple platforms (satellites, UAVs, missiles)



AFRL logo

- Currently equivalent to most accurate mechanical gyroscopes at significantly reduced cost
- Performance headroom for future improvements

**AFRL Focus: Reduced Size & Cost, Increased Sensitivity**

**Benefits to Warfighter:**

- Ultra-high accuracy inertial navigation
- Mid-Term: GPS accuracy for 1-2 hours in GPS denied environment
- Long-Term: GPS accuracy for 10-12 hours in GPS denied environment
- Pervasive application across DoD from submarines through aircraft to space vehicles
- Ability to dynamically trade off precision and bandwidth (update rate)

**Problem:**

- DoD navigation and targeting have become highly dependent on Global Positioning System
- Naturally occurring atmospheric scintillation and adversarial spoofing or jamming can create GPS denied environments in which the warfighter operates
- Presently available INS are either too inaccurate or too expensive to replace GPS guidance for even short periods of time
- Cold atom based interferometry for navigation can be further developed to meet the specifications of accuracy and cost as well as size and power

**Programmatic:**

- POC: Steven M. Miller  
AFRL/RVB, DSN 478-2807
- Current: 6.1 Research task (TRL 3)
- FY10: Effort poised to split
  - Mid-term effort high accuracy/moderate size transitioning to 6.2 research effort
  - Long-term effort, 6.1, continues to reach higher accuracy, miniaturization and lower power requirements

## What Is It?

- 6.1 research focused on utilizing cold atoms to allow INS to operate error free longer

## Warfighter Benefit:

- Could enable error free navigation in GPS denied environments

## Key Date(s):

- High accuracy/moderate size effort transitioning to a 6.2 research effort in the mid-term



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# Summary



- **AFRL vision, strategy, and processes in place to address many areas of interest to EUCOM & AFRICOM**
- **Technology efforts already making an impact on areas of interest**

**Technology efforts can inform EUCOM & AFRICOM IPL processes**



# BACKUP

**AFRL**

THE AIR FORCE RESEARCH LABORATORY  
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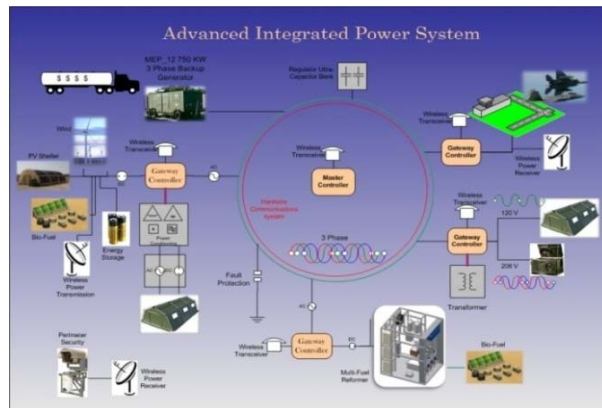


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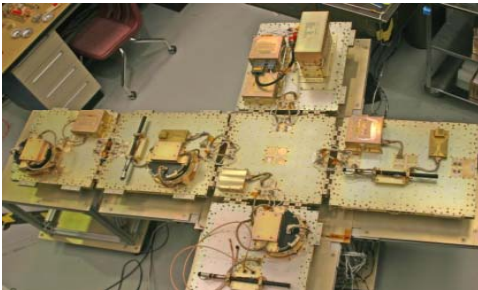




# Plug-and-Play Satellite (PnPSat)



- **Concept:**



Plug-and-play approach (similar to desktop USB) with automated mission and spacecraft design



- **Benefits to Warfighter:**

- Field capability on orbit within weeks or months
- Tailorable to broad range of mission needs
- Significantly reduced spacecraft development costs

- **Problem:**

- Spacecraft development generally takes 2-10+ years
  - Unable to respond to urgent needs in space
  - Technology often dated by launch & new capability takes years to deploy
  - Costs are high to maintain an engineering team for multiple years to custom design spacecraft

- **Programmatics:**

- POC: AFRL/RV, Maurice Martin, 505-853-4118
- PnPSat-1 completed environmental tests in Mar 09 as proof of concept
- PnPSat-2 operational pnp hardware and software will be at CDR in Sept 09
- A commercial version of pnp avionics is being implemented by Sierra Nevada Corp on ORBCOMM-2 to fly in FY10
- TRL: 5





# Solid Propulsion Technologies for Launch



## Concept:



Advanced solid propulsion technologies supporting lower cost, smaller vehicles/increased payload

## Benefits to Warfighter:

- Rapid launch of space assets
- Augmentation of existing capabilities
- Increased payload capability, reduced cost

## Problem:

- Space Access is expensive and not responsive to warfighter timelines
- Warfighter needs augmentation of existing capabilities with “little” notice

## Programmatics:

- POC: AFRL/RZ, John Remen, DSN 525-6428
- TSSS Phase I Demos completed 2QFY09 (TRL 5)
- PAP A2S & A3S to demo above technologies to TRL 6
- Family of Motors (1<sup>st</sup> stage) demo complete in FY10
- Integral part of CSM/PGS, ICBM, ORS activities

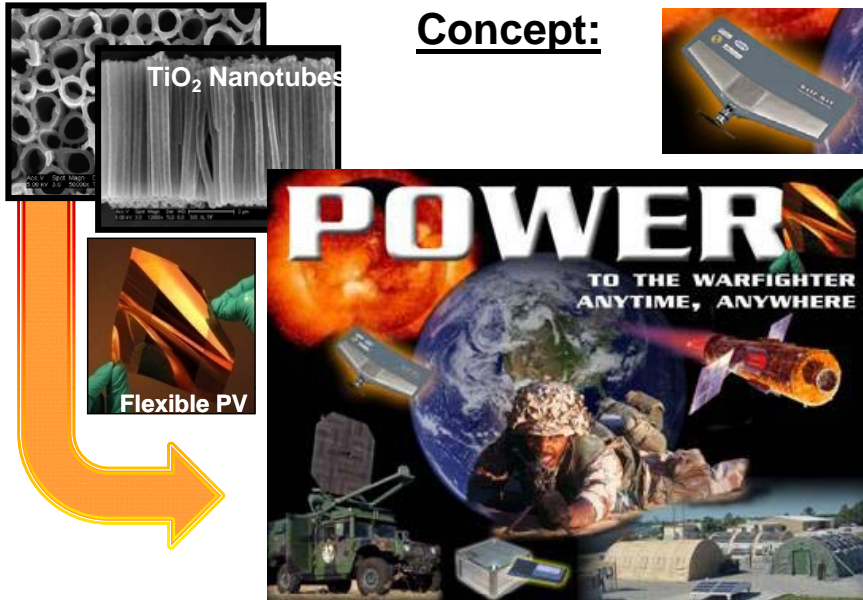


# Energy Harvesting Materials and Devices

*Closely Coordinated with "Electrochemical Energy Storage Materials Program"*



## Concept:



## Benefits to Warfighter

- Lightweight, flexible solar harvesting devices
- Enables portable autonomous power for remote operations
- Technology could transition to the warfighter in micro UAV structures, shelters and special operations applications

## Problem

- Develop/demonstrate lightweight, flexible solar harvesting devices with significantly improved efficiency (>10%), device configuration, cost and lifetimes
- Develop improved active layers for enhanced spectral response
- Design and fabricate nanostructured electrodes for increased charge transport
- Concurrently develop material and solar device processing and manufacturing science

## Programmatics

POC: Lisa Denny, AFRL/RX, DSN 785-9151

### Milestones:

- Q3/FY09 - Reliance Power and Energy Workshop
- Q3/FY09 - AFOSR/ Navy Joint Program Review
- Q4/FY09 - Annual review – flexible solar devices (Phase II)
- Q4/FY09 – Downselect materials approach
- Q2/FY10 - Prototype Solar H2 Generator delivery/demo
- Q4/FY10 - Flexible solar panel delivery RXB/RXQ and Demo



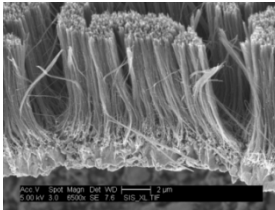
# Electrochemical Energy Storage Materials Program



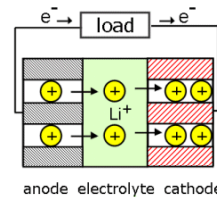
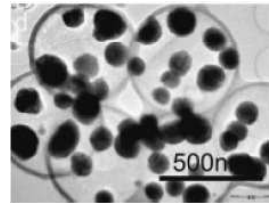
## Concept:



Vertically aligned carbon nanotubes



Carbon Spheres w/ encapsulated nano-catalyst



## Benefits to Warfighter

- High energy & power density rechargeable batteries for small and micro UAS
- Improved life portable fuel cell systems for in field recharge of UAS batteries and deployed comm/ comp systems

## Problem

**Expand performance envelope for electrochemical energy storage devices with nanostructured materials**

- Develop Nanostructured Electrode Materials
- Develop Tailored Electrolyte Materials
- Investigate New/Alternate Approaches
- Integrate & Demonstrate Prototype Cells

## Programmatics

POC: Patrick Carlin, AFRL/RX, DSN 785-9162

### Milestones

- 1Q/FY10 - UCo D. Solid State Li D-Cell
- 2Q/FY10 - CMU D. graphene based electrodes
- 4Q/FY10 - EIC D. Carbon Sphere Li Battery (>600 Wh/Kg)
- 2Q/FY11 - A123 D. 1Ah & >300 Wh/kg at 2C Cells Ultracell D. 50 XX55 Fuel Cells
- 4Q/FY11 - UCo D. Solid State Li BA2590 (>500 Wh/Kg)

\* D. = Deliver



# Battlefield Renewable Integrated Tactical Energy System (BRITES)



## Concept:



Development of flexible soldier portable rechargeable battery for high power draw devices

## Benefits to Warfighter:

- Rechargeable battery capable of relatively high rate discharge
- Significantly reduced weight over legacy primary/secondary batteries
- Improved safety over currently fielded lithium ion batteries
- Enables continuous power when hybridized with energy dense source

## Problem:

- High power devices suffer from low energy densities and vice versa
- High rate primary batteries are discarded after partial use
- High cost associated with primary battery use

## Programmatics:

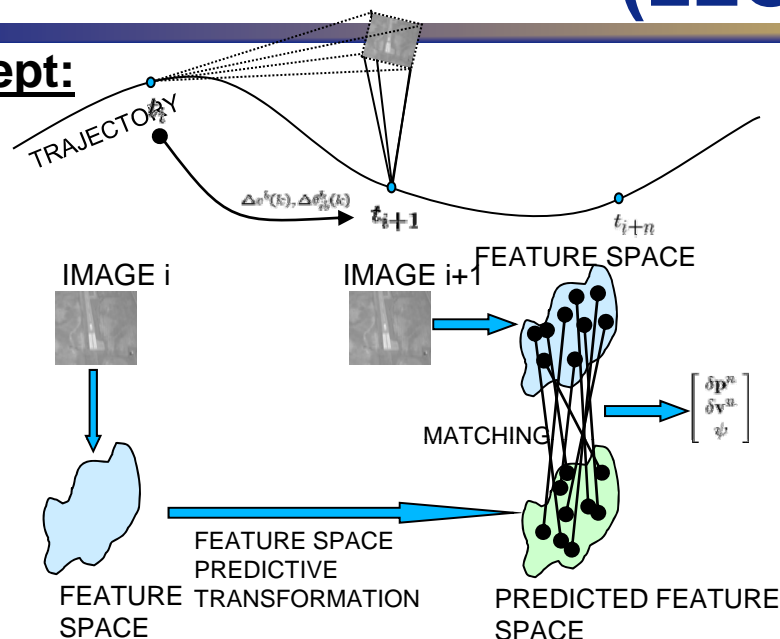
- POC: AFRL/RZ, Lt Mark Roosz, DSN 785-0654
- TRL: 7
- Spiral I and Spiral II transitioned and currently deployed
- Spiral III procured and in Developmental and Operational Testing
- Addresses primary need for field rechargeable Li-Ion batteries from AFSOC



# LADAR/EO GPS Atomic Clock Nav Demo (LEGAND)



## Concept:



## Benefits to Warfighter:

- Precision navigation through GPS outages in military environments where GPS is likely unavailable
  - Urban canyon, indoor, jamming
  - Featureless scenes unsuitable, e.g. over ocean
- Image database/route preplanning not required
- Low cost size, weight, power applications, e.g. small UAV

## Problem:

- GPS may be denied due to jamming or signal obscuration e.g. in urban canyon or indoors
- Inertial navigation systems drift with time and require external updates to maintain precision
- Tightly-coupling on-board “imaging” sensor(s) with low cost inertial to constrain drift of nav solution
  - No prior database of reference imagery
- Incorporation of benefit from fewer than 4 GPS satellite measurements, when available
- Atomic clock aiding for rapid GPS reacquisition

## Programmatic:

- POC: Don Venable, AFRL/RYRN, DSN 785-6127
- TRL 5 in FY 10
- Next steps
  - FY 10 real time demo of single ship LADAR and EO integrations
  - Multi-vehicle collaborative navigation study: FY 11+
    - Collaborative Robust Integrated Sensor Positioning (CRISP)

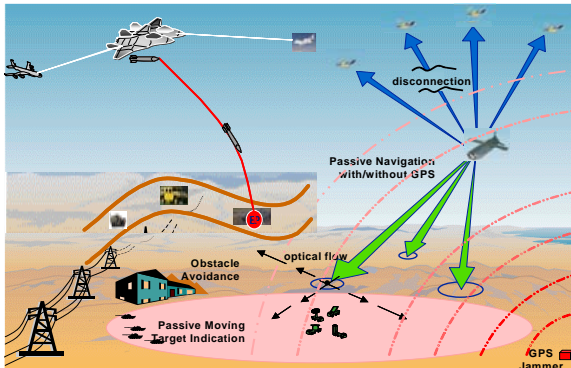




# Optical Flow Enhanced Navigation & Seeker Exploitation (OFFENSE)



## Concept:



Vision based navigation and position updating technologies to augment GPS/INS enabled munitions and UAVs for robust precision target engagement

## Problem:

- GPS is susceptible to jamming and denial (day w/out satellites)
- Robust ego-state estimation and IMU fusion techniques are required to enable precision navigation and targeting:
  - Multi-aperture wide field of regard sensors
  - Robust ego-motion estimation
  - Robust global localization
- All source data fusion engine will allow precision navigation in the absence of GPS

## Benefits to Warfighter:

- Robust navigation for munitions and UAVs in degraded or denied GPS environments
- Enhanced capability to employ munitions and small autonomous vehicles in urban terrains
- Reduced TLE for targeting

## Programmatics:

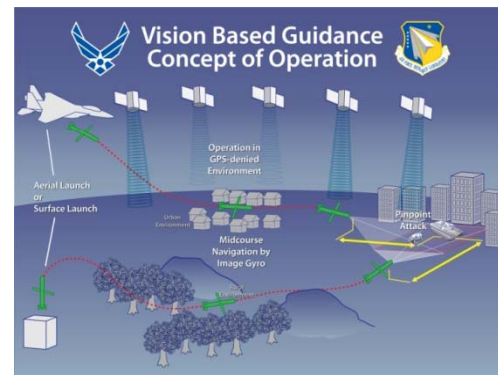
- POC: Dr. Timothy J. Klausutis, AFRL/RW, 850-883-0887
- Current TRL: 3-4
- Algorithm/Software test-bed established, performance evaluation study underway
- Milestones:
  - FY09: Ground mobile data collection
  - FY10: Captive flight test data collection
  - FY10: Performance analysis against varied environments and maneuvers
  - FY11: Real-time implementation study



# Airborne Image Gyro (ABiG)



## Concept:



Develop a low-cost vision based navigation technology to enable precision navigation of unmanned air vehicles (UAVs) and missiles in degraded or denied GPS environments

## Problem:

- GPS is susceptible to jamming and denial (day w/out satellites)
- Robust ego-state estimation and IMU fusion techniques are required to enable precision navigation and targeting:
  - Robust ego-motion estimation (translation and rotation rate estimates)
- Image matching to pre-captured imagery providing precision geo-registration (position estimation)
- Multi-aperture vision and sensor fusion
- Day and night-time capable sensing

## Benefits to Warfighter:

- Affordable navigation sensing and processing for missiles and UAVs
- Provides low cost alternative to GPS, which is vulnerable to jamming
- Augment existing GPS navigation systems enabling precision navigation in degraded GPS environments

## Programmatics:

- POC: Dr. Timothy J. Klausutis, AFRL/RW, 850-883-0887
- Current TRL: 3; Final TRL: 5/6
- Program set to start FY09-FY10 (awaiting finalization of MOU)
- International Cooperative Research & Development with Japan TRDI and U.S. ARMY (AMRDEC)
  - FY09-FY10: Startup and system definition
  - FY10-11: Preliminary processing algorithms
  - FY10-11: Hardware implementation and real-time implementation
  - FY12-13: Performance Evaluation

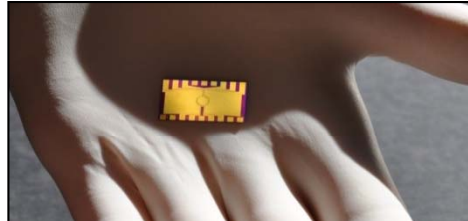


# Cold Atom Inertial Navigation Systems (INS)



## Concept:

- Cold atoms: a gas of atoms slowed by lasers
- Cold atoms are incredibly sensitive to inertial forces
- Cold atom sensors enable ultra-accurate navigation w/o external reference (e.g., GPS-denied environments, space)
- Adaptable to multiple platforms (satellites, UAVs, missiles)



AFRL designed & fabricated atom ring trap

- Currently equivalent to most accurate mechanical gyros at significantly reduced cost
- Performance headroom for future improvements

**AFRL Focus: Reduced Size & Cost, Increased Sensitivity**

## Problem:

- DoD navigation and targeting have become highly dependent on Global Positioning System
- Naturally occurring atmospheric scintillation and adversarial spoofing or jamming can create GPS denied environments in which the warfighter operates
- Presently available INS are either too inaccurate or too expensive to replace GPS guidance for even short periods of time
- Cold atom based interferometry for navigation can be further developed to meet the specifications of accuracy and cost as well as size and power

## Benefits to Warfighter:

- Ultra-high accuracy inertial navigation
- Mid-Term: GPS accuracy for 1-2 hours in GPS denied environment
- Long-Term: GPS accuracy for 10-12 hours in GPS denied environment
- Pervasive application across DoD from submarines through aircraft to space vehicles
- Ability to dynamically trade off precision and bandwidth (update rate)

## Programmatics:

- POC: Steven M. Miller  
AFRL/RVB, DSN 478-2807
- Current: 6.1 Research task (TRL 3)
- FY10: Effort poised to split
  - Mid-term effort high accuracy/moderate size transitioning to 6.2 research effort
  - Long-term effort, 6.1, continues to reach higher accuracy, miniaturization and lower power requirements